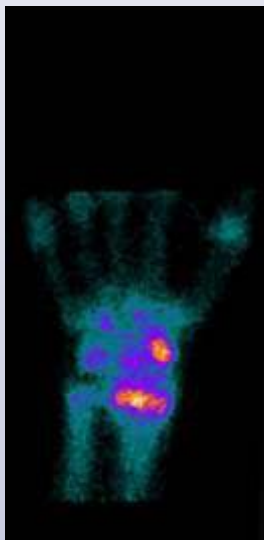




Nuclear Medicine

Central Coast Nuclear Medicine



Nuclear Medicine
in General Practice



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A copy of a more detailed booklet can be downloaded from www.i-med.com.au

■ Introduction:

Nuclear Medicine techniques are designed to assess the functional state of a number of organ systems. The function of an organ can be disturbed well before any structural changes become apparent.

A radiopharmaceutical is a tracer, meaning that it does not alter the system it is designed to interact with in any way. The variety of radiopharmaceuticals that are available allow for the investigation of virtually all systems of the body.

By far the majority of standard radiopharmaceuticals use ^{99m}Tc Technetium as the radioactive component. This has a short half life of approximately 6 hours, which helps to minimise the radiation dose to the patient. It produces Gamma rays that are of sufficiently high energy to penetrate the tissues so that they can be detected externally by a Gamma camera.

Technetium is also chemically active and this allows it to be bound to a variety of pharmaceuticals that determine its biodistribution. If it is linked to a phosphate it will enter the phosphate pool of the body and some will be taken up by the bones in proportion to the activity of the osteoblasts at that site. Linking it to an isonitrile allows assessment of myocardial perfusion, to a small molecule that filters through the kidneys will show renal function and drainage, to a particle injected into a systemic vein will show lung perfusion etc. Radiopharmaceutical design is a key component of the practice of Nuclear Medicine.

The second key component is the Gamma camera and associated computer system. This determines the distribution of the radiation and hence the radiopharmaceutical in the body. Many processes can be quantified such as renal differential function, gastric emptying etc. The images we perform can be static, dynamic (over seconds to assess renal perfusion or over days to assess colonic transit), planar (like an X-ray) or tomographic (like CT).

Some practitioners are critical of the low resolution of Nuclear Medicine images particularly when compared to modern CT and MR images. The detail of Nuclear Medicine is not in the structure, but in the function. A bone may look intact with X-ray, but a bone scan showing us osteoblastic activity will readily demonstrate a fracture soon after it occurs.

It should be noted that Nuclear Medicine is often very sensitive but it can be non-specific and it may well be appropriate and necessary to combine the findings of our study with those of another modality such as X-ray, CT or MRI.

■ At a Glance:

Cardiac

- Evaluation of known or suspected coronary artery disease
- Measurement of left ventricular function

Bone Scanning

- Skeletal metastases or malignancy
- Suspected fracture
- Infection
- Overuse syndromes eg. Shin splints/stress fractures
- Chronic pain syndromes eg. Back pain associated with degenerative facet joint disease
- Ongoing pain following joint replacement and spinal surgery
- Metabolic bone disease eg. Paget's disease

Lung

- Suspected pulmonary emboli
- Lung reduction surgery planning
- Right to left shunts
- Lung clearance studies

Urinary Tract

- Renal scarring following urinary tract infection in children
- Suspected obstruction eg. PUJ obstruction
- Follow up of urinary reflux
- Assessment of hypertension where renal artery stenosis is suspected
- Estimation of differential function

Endocrine

- Hyperthyroidism; allows differentiation of Graves' disease from subacute thyroiditis
- Evaluation of thyroid nodules

Gastrointestinal

- Oesophageal motility, gastric emptying and colonic transit
- Inflammatory bowel disease
- GI bleeding
- Meckels diverticulum

Hepatobiliary

- Diagnosis of acute and chronic cholecystitis
- Focal hepatic lesions
- Biliary leak (eg. Post cholecystectomy, trauma)

Cardiac:

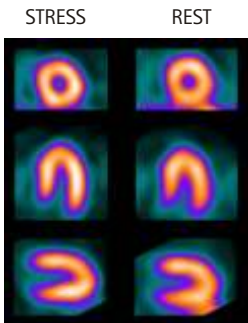
Myocardial perfusion scintigraphy (MPS) is a well established technique for non-invasive assessment of the heart. It is used to:

- Assess the presence and degree of coronary artery obstruction in patients with suspected disease
- Aid in the management of patients with known disease
 - determine likelihood of future events (e.g. after infarction or in relation to non-cardiac surgery)
 - determine the functional significance of a known coronary lesion
 - assess adequacy of revascularisation

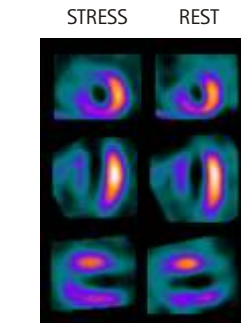
Gated blood pool imaging provides accurate quantitation of the left ventricular ejection fraction in a variety of clinical situations (e.g. after myocardial infarction, before and during chemotherapy, cardiomyopathy etc.)

Procedural Techniques:

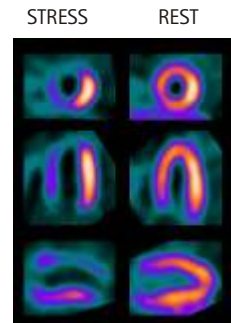
1. Fast for 6 hrs prior to study and NO caffeine-products for 24 hrs prior to study.
2. No episodes of angina for 48 hrs prior to study.
3. Rest injection and rest imaging (1 hr).
4. Stress procedure 1-3 hrs later or on another day with either exercise (treadmill, bike) or dipyridamole, then imaging (1 hr).
5. Certain medications may need to be ceased.



1. **NORMAL** Normal perfusion seen in both the stress and rest images



2. **INFARCTION** Large, fixed defect (i.e. unchanged in both the stress & rest images) in the anterior and anteroseptal walls.



3. **ISCHAEMIA** Large perfusion defect seen in the stress images in the anterior, septal and inferior walls that normalises at rest consistent with severe ischaemia.

■ Bone Scanning:

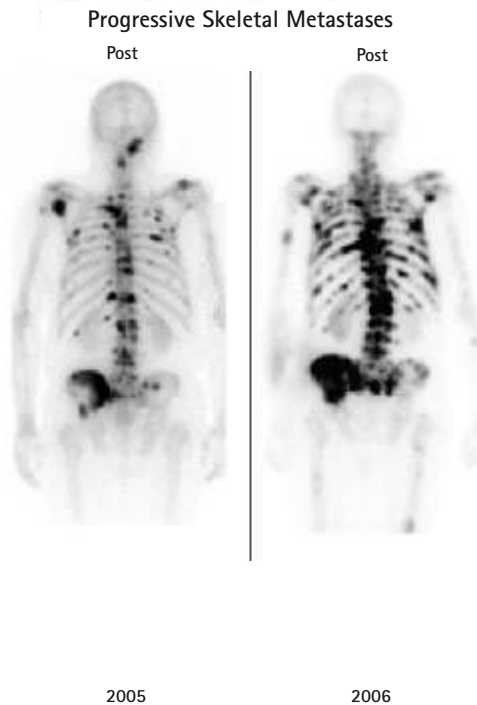
This is an easy and accurate technique that allows assessment of the entire skeleton. Regions of abnormally increased activity imply increased osteoblastic activity in response to a variety of pathologies.

Procedural Techniques:

1. Initial injection and dynamic images 15 min.
2. Delay of 2-4 hrs depending on type of scan with imaging for 30-80 min.
3. Patient is instructed to drink extra fluids and to empty their bladder regularly.

Malignancy (primary or secondary):

Whole body bone scanning is usually performed and is positive in the majority of malignancies with bone involvement. Serial studies will allow assessment of disease activity in response to therapy.



Trauma/Fracture:

The bone scan will become positive soon after fracture occurs in a healthy skeleton because of the rapid development of the osteoblastic response of healing. Overuse syndromes (such as shin splints) are also well demonstrated.

Plantar Feet



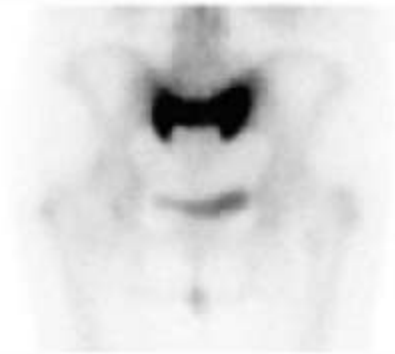
1. Metatarsal fracture

Anterior Tibiae



2. Bilateral tibial stress response
(Shin Splints)

Posterior Pelvis



3. Typical fracture pattern
associated with osteoporosis

Infection:

This also becomes positive soon after osteomyelitis is established. Septic arthritis can take longer to show changes and the findings can be less specific. Assessment of cases complicated by co-existent trauma (eg. accidental or surgical) will usually require combined assessment with gallium scanning.

Many other processes can also be assessed.

Avascularity (eg. Perthes disease, spontaneous osteonecrosis at the knee, post-traumatic etc).

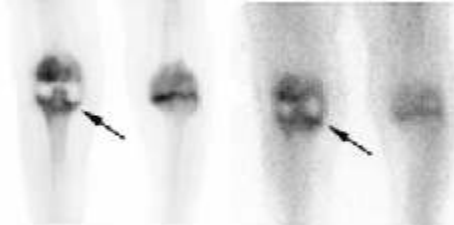
Metabolic disease (eg. Paget's).

Soft tissue inflammation (eg. Tendonitis, cellulitis, enthesopathy etc).

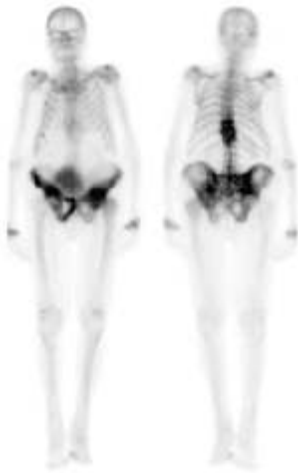
Painful joint prosthesis.

Painful back (disc degeneration facet arthritis, crush fracture).

Anterior Statics



Delayed Bone 24 hr Gallium



Paget's Disease

Palmar Blood Pool



Delayed Bone Scan



de Quervain's tenosynovitis

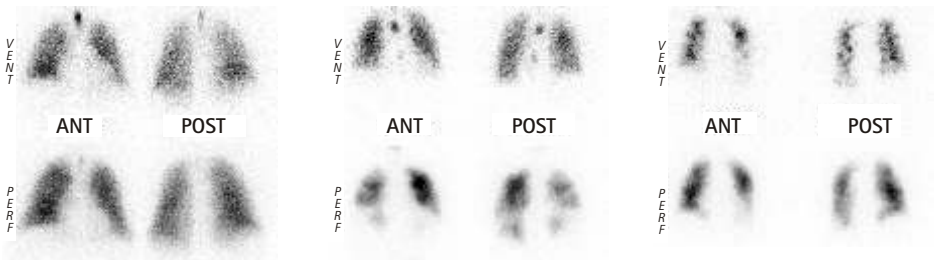
Lung:

Ventilation/Perfusion (V/Q) lung scans remain a useful technique for assessment of patients with suspected pulmonary embolism and for follow up of documented embolism. The classic abnormality is one in which ventilation is maintained with decreased or absent perfusion in a segmental distribution (**segmental mismatch**).

The same images allow quantitation of ventilation and perfusion to regions of the lungs, which is a useful technique prior to lung reduction surgery.

Procedural Techniques:

1. A current chest X-ray is required for interpretation of the lung scan.
2. Initial ventilation study followed by perfusion study.
3. Duration of study 1 hr.
4. Lung clearance studies require ventilation only followed by 20-30 min of imaging.



1. **NORMAL** uniform tracer distribution in lung fields in both phases

2. **PULMONARY EMBOLISM** normal ventilation with segmental areas of perfusion mismatch consistent with a high probability for pulmonary embolism

3. **AIRWAYS DISEASE** scattered areas of reduced activity in the lung fields in both phases without significant mismatch

Urinary Tract:

Renal Scanning is divided into two main groups.

DTPA Scanning:

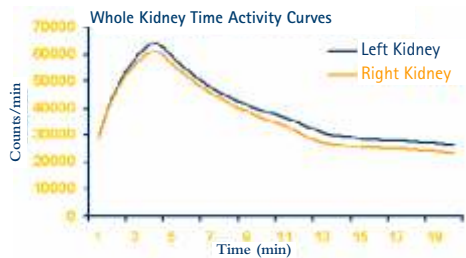
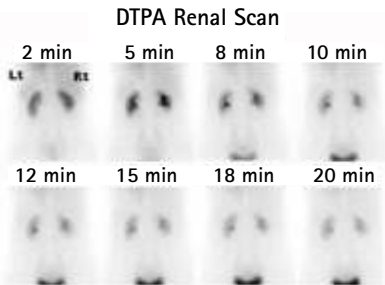
This agent clears via glomerular filtration and determines:

- a) differential (and total) function
- b) drainage of the kidneys and ureters
- c) presence of vesicoureteric reflux

Mag3 is an agent that is mainly cleared by tubular secretion and performs similar assessment to DTPA.

Procedural Techniques:

1. DTPA or MAG3 Bolus injection followed by 20 min of imaging.
2. Frusemide may be administered to assess clearance.
3. Captopril study Tracer is injected 1 hr after oral Captopril and imaging is performed for 30 min.
4. DMSA scanning requires imaging for 40 min after a 3 hr delay.
5. Isotope cystogram - Tracer is administered via a urethral catheter until the patient micturates.



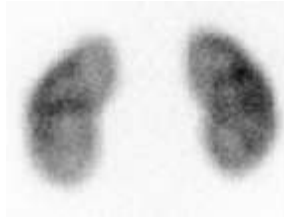
Normal DTPA Study

DMSA Scanning:

This agent slowly accumulates after intravenous administration in the proximal convoluted tubular cells and is used to assess:

- a) functional integrity of the renal parenchyma with reasonable morphologic detail.
- b) differential function.

DMSA Renal Scan



Normal Scan

Renal Scarring

DMSA is a very sensitive technique for assessment of the renal parenchyma and demonstrates focal scarring very well. It will also be abnormal during an episode of acute pyelonephritis with serial studies showing if there is any evolution of the acute changes to a chronic scar.

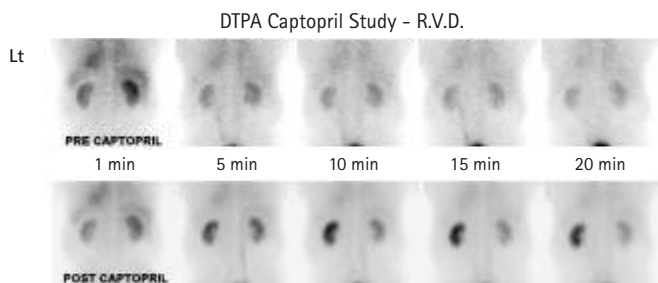


Right renal scarring normal left kidney.

Renovascular Disease

This accounts for a small proportion of patients with hypertension. The study is usually performed in two parts. The baseline study may well be normal or near normal. The study is then repeated after an ACE inhibitor (usually Captopril) is administered. This suppresses the vasoconstriction associated with elevated serum angiotensin and causes a number of changes in the affected kidney such as a decrease in differential function and enhanced cortical retention.

This technique is less sensitive when there is bilateral disease or significant renal impairment.



Persistent left cortical activity in the post Captopril study is typical of significant renovascular disease.

Differential and Total Renal Function:

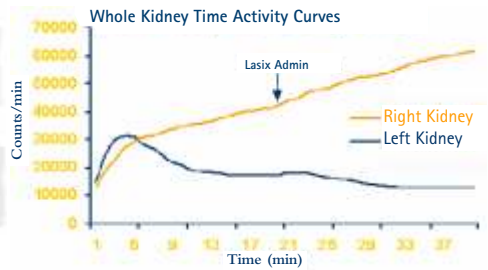
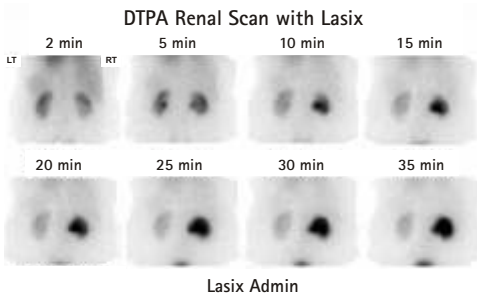
The rate of clearance of DTPA and the proportion of DMSA retained in the kidneys are accurate and reproducible measures of differential function. GFR can be estimated by assessing the rate of clearance of DTPA from the plasma by taking two (or three) blood samples 2-3 hrs after administration of the tracer. This technique is not available in all departments.

A variety of functional abnormalities can be assessed:

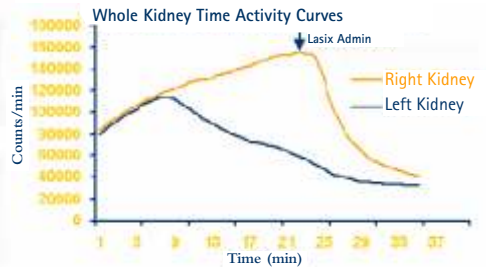
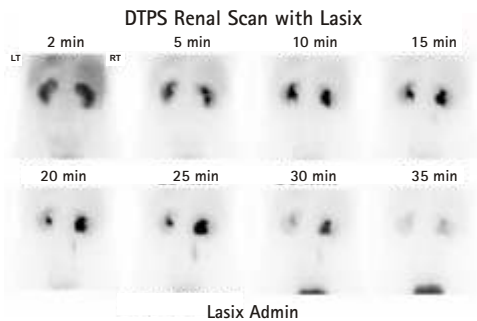
Functional Obstruction

Urinary tract dilatation is often evident with ultrasound and CT but the presence of dilatation does not necessarily mean that the system is significantly obstructed. DTPA with scanning with LASIX provocation will help to determine adequate drainage of the system or not. The differential function of the affected kidney can also be assessed.

The presence of significantly reduced relative or total function and the presence of severe hydronephrosis reduces the sensitivity of the study.



Right Pelviureteric obstruction



Study following Pyeloplasty with relief of obstruction.

■ Endocrine:

Thyroid scanning is a simple technique that allows assessment of:

- altered thyroid function
- nodular thyroid disease

Parathyroid scanning detects parathyroid adenoma or hyperplasia in the typical distribution in the parathyroid glands or in an ectopic position (e.g. mediastinum). It is often used pre-operatively to assist with surgical planning.

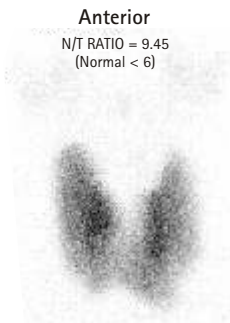
A) Thyroid Procedural Techniques:

1. No iodine for 6 weeks prior to the study (includes radiographic contrast and amiodarone).
2. Initial injection followed by imaging 20 min later. Imaging lasts 30 min.

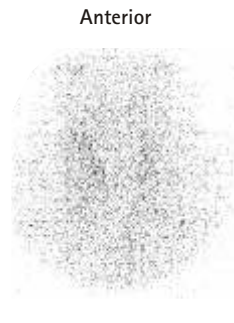
B) Parathyroid:

No preparation.

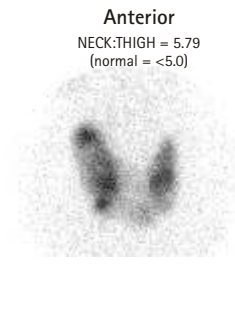
Endocrine Thyroid:



1. **GRAVES' DISEASE** diffusely enlarged thyroid with uniform tracer distribution in both lobes. Thyroid uptake is elevated consistent with hyperthyroidism.



2. **SUBACUTE THYROIDITIS** no significant uptake in the thyroid associated with diffuse inflammation.



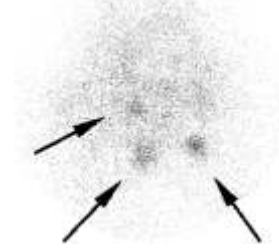
3. **MULTINODULAR GOITRE** moderately enlarged gland with irregular tracer distribution in both lobes. No dominant photopaenic abnormalities.

Endocrine Parathyroid:

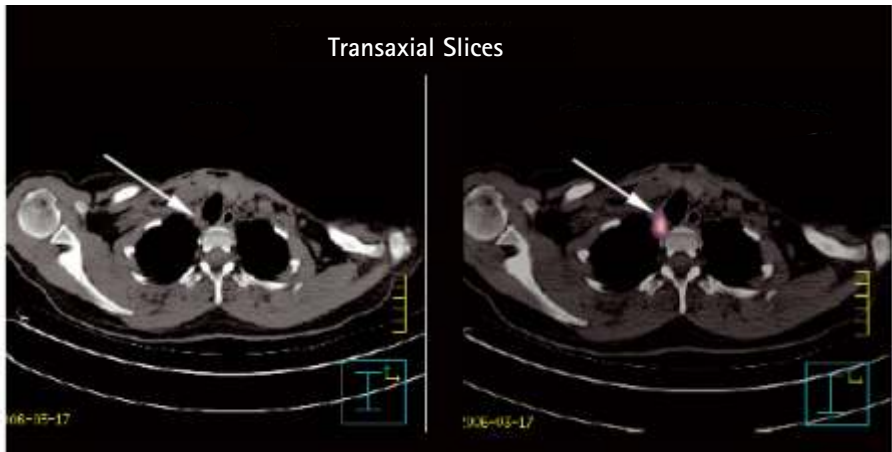
Anterior Sestamibi 10 min



Anterior Sestamibi 3 hr



1. Parathyroid hyperplasia or adenoma formation. Mildly increased activity is evident at 3 sites in the images at 10 min. At 3 hr the activity has cleared from the normal thyroid tissue with activity persisting at the 3 sites noted at 10 min.



CT

CT with fused sestamibi SPECT

2. The exact position of an abnormal parathyroid can be determined using image fusion (see page 17).

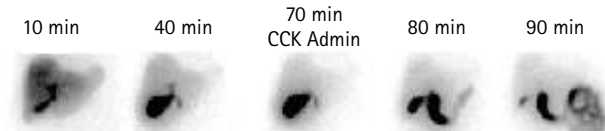
■ Hepatobiliary:

This technique allows assessment of many physiological aspects including;

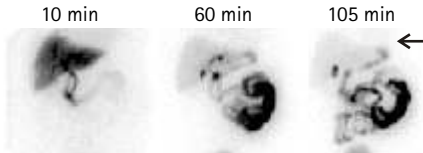
- liver function
- patency of the biliary tract
- gallbladder function
- post-operative complications

Procedural Techniques:

1. Fasting for 4 hrs prior to the study.
2. Initial injection followed by imaging for 1 hr.
3. Imaging may continue for a further 30-60 min following IV morphine if the gallbladder is not visualised initially or if cholecystikinin is administered to assess gallbladder emptying.



Normal study with normal gallbladder filling and normal emptying in response to CCK.



Abnormal study. Poor gallbladder filling with no response to CCK. Prominent duodenogastric reflux (arrow).



Normal gallbladder filling with no response to CCK stimulation consistent with acalculous biliary disease (chronic acalculous cholecystitis).

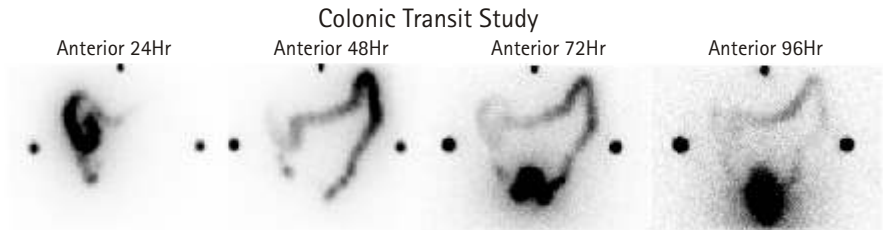
■ Gastrointestinal:

A variety of studies can be performed to assess gastrointestinal physiology including;

- oesophageal transit
- gastro oesophageal reflux
- gastric emptying
- colonic transit
- presence of ectopic gastric mucosa (typically Meckel's diverticulum)

Procedural Technique:

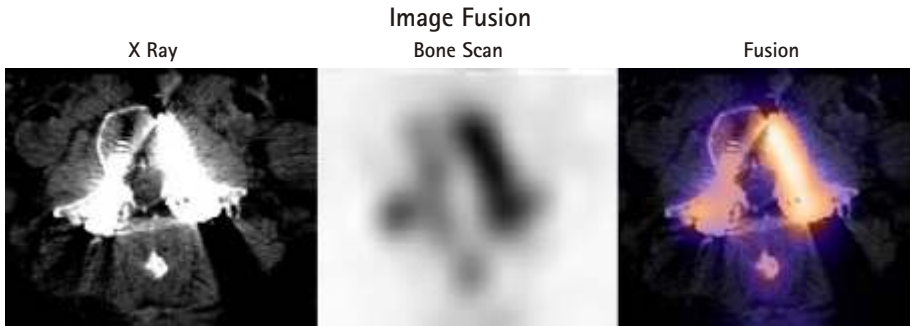
Gastric emptying Fast for 6 hrs prior to ingestion of tracer, images taken over 2 hrs.



Grossly abnormal study with marked persistence of activity in the rectosigmoid colon consistent with obstructed defecation. There is also some delay in colonic transit, presumably as a secondary effect.

■ Fusion:

Advances in image processing now allow accurate superimposition (**image fusion or co-registration**) of nuclear medicine (**Functional**) data with X-ray or MRI (**Anatomical**) data providing more accurate assessment of the function of an anatomic abnormality and more accurate definition of the distribution of a functional abnormality.



Fused (co-registered) tomographic images giving precise anatomical localisation to the nuclear medicine abnormalities and localise the abnormal activity to the line of an orthopaedic screw.

